Overhead Capacitive Sensing System For Driver Alertness Self Monitoring

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RESULTS OF ASCI MINDS™ DRIVER ALERTNESS SYSTEM
FIELD TRIALS BY PERFORMANCE FOOD GROUP (PFG)

In December, 2002, ASCI was approached by the PFG, a long-haul trucking firm which delivers food supplies to chain restaurants throughout the western U.S. from its warehouse in McKinney, TX, to outfit one of the firm's Freightliner-brand tractors with MINDS for a 60 day evaluation period. The objectives of the evaluation were:

- To design an installation method appropriate for "condo-cab" tractors used by PFG and many long-haul trucking firms.
- To assess the efficacy and appropriateness of various MINDS alerting methods.
- To create long-term (>24 hours of driving time) data files which could be easily downloaded by safety personnel.
- To efficiently create reports of driver alertness for review and follow-up action by management.

In mounting the MINDS array in a vehicle, a key constraint is that the array must be positioned horizontally (+/- 15°) no more than about 8" above the driver's head. For passenger vehicles this is not a problem as the headroom is typically 2" to 6", but sleeper-cabs used by most long haul trucking firms provide several feet of headroom to allow access to the bed area behind the seats. In addition, most of these cabs have air-cushion seats, which provide vertical travel of 6" or more. If the MINDS array were to be mounted to the ceiling or cab side-wall, seat position adjustments could easily violate the 8" maximum headroom requirement.

ASCI engineers reviewed the interior dimensions and air-cushion seat design used in the PFG tractors, and determined that a bracket attached to the seatback structure would be most appropriate mounting mechanism for the ASCI MINDS overhead array. This design allows the MINDS array to always be at a fixed distance above the driver's head, regardless of seat vertical adjustment and air cushion "floating". The bracket consists of two, approximately 30" long sections of electrical conduit formed to an angle of about 90°, to which is attached the MINDS array:

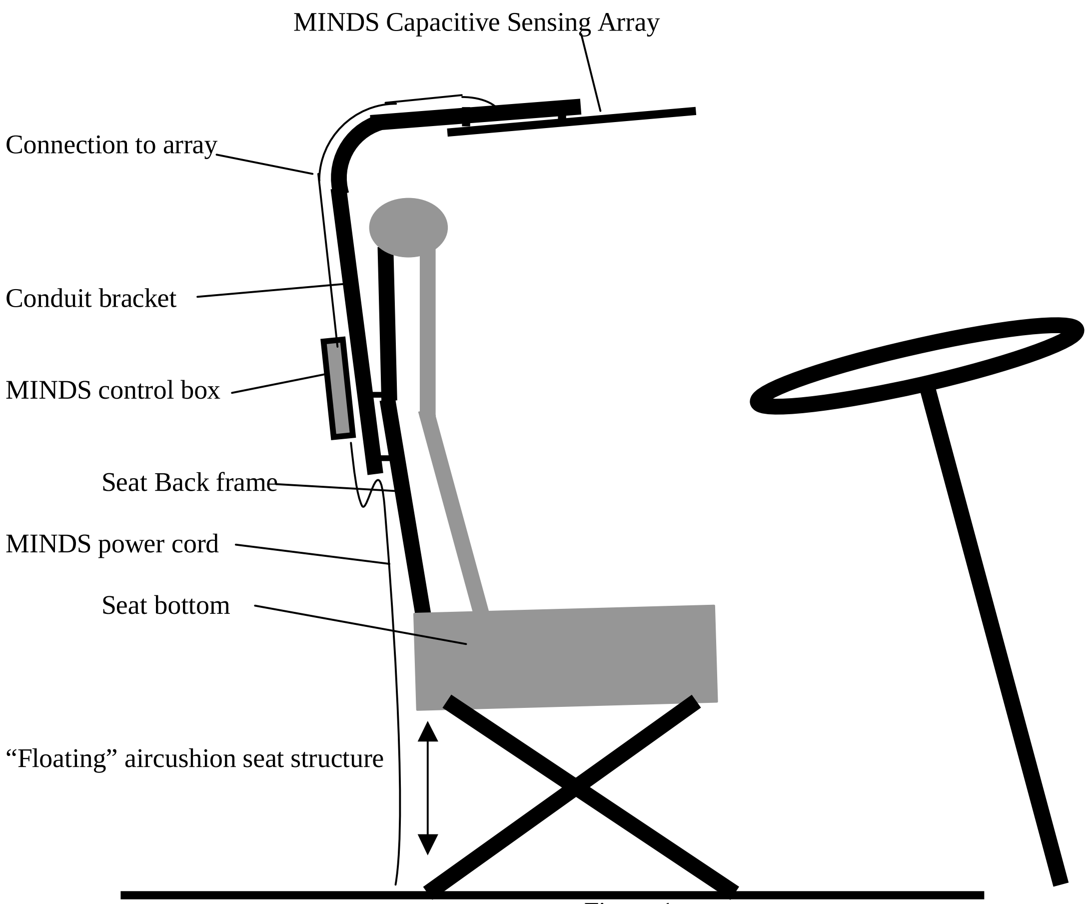

Figure 1

This bracket was fabricated, tested, and installed in the PFG tractor. In volume applications, the installation time is estimated at 15 minutes by a trained installer. The MINDS system installed in the PFG tractor consisted of the MINDS overhead array, the MINDS control/alerting box (approximate size of a Palm PDA), and wiring.

The MINDS box provides LED and audible alerts when the particular driver's relative alertness exceeds a pre-determined threshold. The threshold is controlled by the embedded MINDS software or optionally by a user-adjustable encoder. This feature allows the user (driver or management) to adjust the threshold and thereby change the detection sensitivity. In Figure 3 below of data captured during a passenger car test drive, the threshold (blue) is set at 4.000 and the MINDS detector output (green) exceeded this during the tenth minute of this sample. The red line (count) is the number of samples above the threshold during the previous five minutes. MINDS is programmed to activate stage one alerting when the count exceeds 99, and stage two alerting when the count exceeds 249.

Given MINDS sampling rate of 10 Hz, these values represent 3.3% and 8.3% respectively, of the MINDS output exceeding the threshold over the previous five minutes. These values were derived from original research data in which cumulative detection time was plotted against cumulative driving errors (Figure 2). That data suggested that false positives could be minimized by using a cutoff requiring about 3% of samples over five-minutes above the threshold as a reliable early indication of the onset of true sleepiness.

By triggering alerting devices early in the transition from awake to drowsy, sleep research has shown it is possible to maintain functional alertness of the driver long enough to find a safe stopping place to sleep or change drivers (2002 Conversation with Richard Grace, Ph.D., Carnegie Mellon National Robotics Engineering Center).

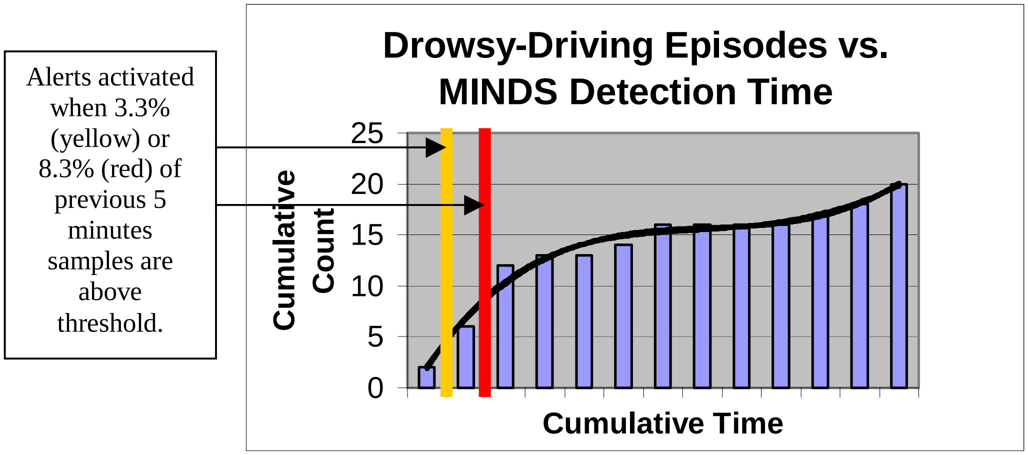

Figure 2

In the current version of ASCI MINDS software, the detection sensitivity is adjusted by changing the threshold, and the alerting sensitivity is adjusted by changing the count. In the system provided to PFG, two modes of alerting were available: yellow (count>99) and red (count>249) LED's, and a buzzer. The one-second buzzing sound was activated at a 3 second repeat when count exceeded 99, and at a one second repeat when count exceeded 249. Management elected to install the control box behind the seat, out of sight of the driver, to reduce possible distraction from the LED's and to prevent the driver from adjusting the detection sensitivity. Thus in this test only the buzzer was available to notify the driver of impending drowsiness.

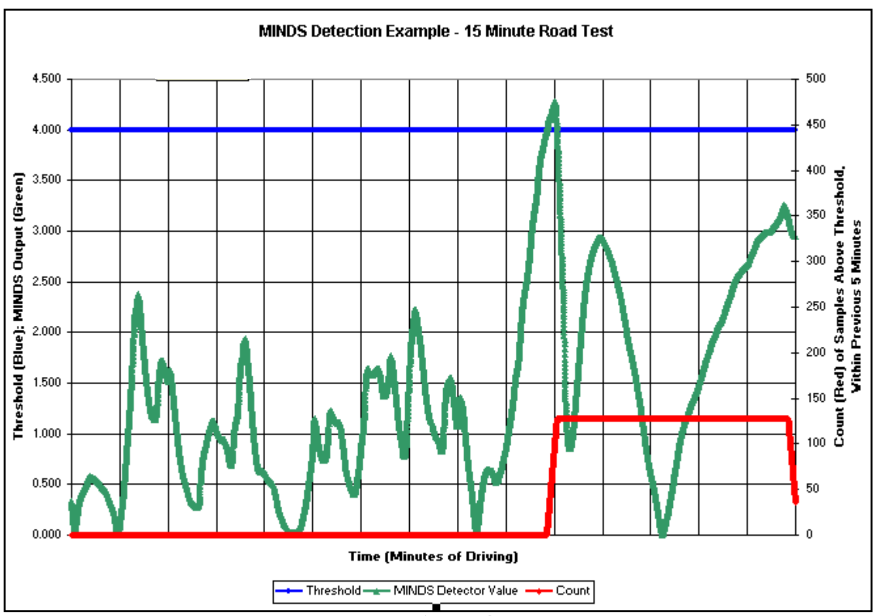

Figure 3

To assess the appropriateness of the tone and volume of the audible alert, after the second week (see below) a one-hour test drive was performed in which ASCI staff adjusted the sensitivity to force activation of the buzzer at both the low repeat cycle and high repeat cycle. Both the driver and PFG management felt the audible alert was loud enough to be heard above background truck noise, but not so loud as to startle the driver and risk over-correction.

The tractor with MINDS system installed was driven on its regular route for portions of two weeks – two legs totaling approximately 60 hours of drive time. Unfortunately, technical problems arose which reduced the data available to management and ASCI:

- In the first leg, a configuration-programming error de-activated the alert buzzer. Additionally, the tractor's 12 volt power supply outlet experienced voltage spikes beyond the design limit of ASCI MINDS, burning out a chip on one of the three sensors. This caused the algorithm to output a failure condition. No data was obtained for this run. The system was returned to ASCI and repaired.

- In the second leg, the MINDS on-board data log was either not recording properly or was inadvertently erased during downloading to the PFG laptop computer.

- During the test drive, a possible voltage spike caused the raw sensor voltages to shift, necessitating a re-calibration.

- At conclusion of every test, PFG staff had to disconnect and re-connect power in order to download data – a condition not experienced by ASCI staff using ASCI computers. ASCI attributes this to the older model of computer used by PFG, or to improper computer configuration.

- After the data was downloaded and the PFG staff person was in the driver's seat, for unknown reasons the alerting buzzer sounded. ASCI thinks this episode may have been caused by another voltage spike which corrupted the data in some manner. In normal operation, the MINDS software recognizes when a driver is present or absent – and requires twenty minutes of valid (driver-present) data to initiate an alert-condition.

- Due to incorrect date/time chip selection in the unit tested, the date/time needed to be reset each time power was applied. This will be corrected in future MINDS systems.

Additional issues uncovered during the evaluation related to: 1) The format and content of the MINDS on-board data log, while appropriate for ASCI verification of performance, is inappropriate for trucking company management; 2) The data log downloading procedure is cumbersome and prone to errors by personnel not familiar with the software; and 3) The older model of laptop computer available at PFG was slow and cumbersome, leading to data downloading and configuration errors.

The following improvements are being implemented by ASCI to address these issues.

- The MINDS on-board data logging capability as used by PFG, is restricted by size of the on-board memory chip. However, by logging only the minimum alertness, threshold, and count data in a condensed format, trucking company staff in the future will be able to generate an Excel plot similar to Figure 2 above covering about 8 hours of operation (28,800 samples) rather than the current plot-per-page of just 53 minutes (32,000 samples). For more extended data logging requirements, additional memory chips will be needed and this will require hardware redesign, requiring about 6 to 8 weeks.
- The data logger downloading procedure possibly can be automated if an optimized, pre-configured laptop computer is supplied by ASCI. Given that one computer costing approximately $1,500 could serve a fleet of about 50 trucks with installed MINDS units, the cost of supplying this laptop will not be excessive. This limitation of 50 trucks per computer is hard-drive size. Assuming the laptop comes with a 12 gb hard-drive, with 2 gb reserved for plotting software and files (Excel) and 10 gb available for truck data, and further assuming a 50-truck fleet, each truck is allocated 200 mb of disk space. Further assuming that each 40-hours of compressed data requires 120 kb of drive space, the laptop will hold 1,666 hours of data for the fleet of 50 trucks, about equal to one year of data. Of course, the data periodically could be copied to separate storage media to allow multi-year use of the laptop.
- ASCI recommends the MINDS power come from the accessory outlet on the dashboard rather than the accessory outlet in the sleeper cab. This will allow the driver to reset the system should false alerts occur. In addition, we suspect the power spikes may be specific to the outlet in the sleeper cab on this particular tractor.
- ASCI recommends installing a visual "Fatigue Indicator" of driver alertness – preferably located on the driver display panel adjacent to speedometer, RPM, or air pressure gauge. This can be an LED scaled from 0 (very sleepy) to 10 (alert), which will give the driver a self-monitoring cue as to his/her relative alertness. While post-drive assessment of driver alertness by management offers the opportunity to counsel a driver on past alertness problems, it is critically important to train the driver to stop and rest or switch drivers according to the real-time Fatigue Indicator. ASCI suggests both the real-time countermeasure, and post-drive counseling by management, is needed to make this an effective program which reduces accidents caused by drowsy driving.